OPERATIONAL USE OF WEATHER RADAR COMPOSITES IN FLORIDA

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ABSTRACT

A weather radar facsimile network providing rapid collection and compositing of radarscope photographs has been established in Florida by the Weather Bureau in support of Project Mercury. Equipment and operational procedures are discussed in some detail and several synoptic examples of radar compositing from PPI photographs are presented. These examples include echo configurations associated with an easterly wave and two well-organized squall lines that moved across the Florida Peninsula. Radar composites for these situations are compared with coded radar observations and Radar Summary Charts and the advantages and possible future utilization of radar composites are cited.

1. INTRODUCTION

Weather radar compositing, the integration of two or more simultaneous PPI scope presentations, is a natural outgrowth of the progressive establishment of U.S. Weather Bureau radar stations in central and eastern United States. A nationwide electronic system capable of collecting radarscope presentations and automatically compositing them for facsimile transmission would have wide applications in synoptic meteorology and in aviation and severe storm forecasting.

Until an electronic system is operational, one of the most feasible methods of collecting radarscope presentations is regional facsimile transmission and manual composition of radar Polaroid photographs. An experimental network to accomplish this type of compositing was established in Florida by the Weather Bureau early in 1961. The WSR-57 radar stations at Daytona Beach, Miami, and Tampa, Fla., are linked together by a special facsimile network. Photographs transmitted over the network are manually composited with the Miami PPI photograph in Project Mercury Weather Support Group Office at Miami, and the final radar composite is transmitted by facsimile to Cape Canaveral for operational use in forecasting for Project Mercury, the nation's initial manned space-flight program. This radar composite is also available to the District Meteorological Office in Miami.

Ligda [1] has published striking composite pictures of storm systems prepared by fitting together radarscope photographs obtained from a number of radar stations. However, the system used in Florida for Project Mercury, is, to the author's knowledge, the first operational use of composites prepared from current radarscope photographs. This subject was briefly discussed by the writer [2] in 1961.

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2. EQUIPMENT

The network equipment consists of a 4 × 5-inch Press camera with Polaroid back mounted on the main PPI scope of each WSR-57 radar, small size facsimile transmitters at Daytona Beach and Tampa, and transceivers at Miami and Cape Canaveral. The standard Polaroid photograph is too small to show the detail required for satisfactory compositing. A Graflex-Polaroid Press camera, provided with a 75 mm., $f2.8$ Oscillo-Amaton, Wollensak lens, was substituted (fig. 1), thus increasing the picture size by almost 50 percent. This camera produces a 4 × 5-inch print which has proved to be adequate for facsimile transmission and compositing.

A special aluminum camera support mount, weighing much less than the camera, is used to attach the camera to the PPI scope. The radar room must be completely

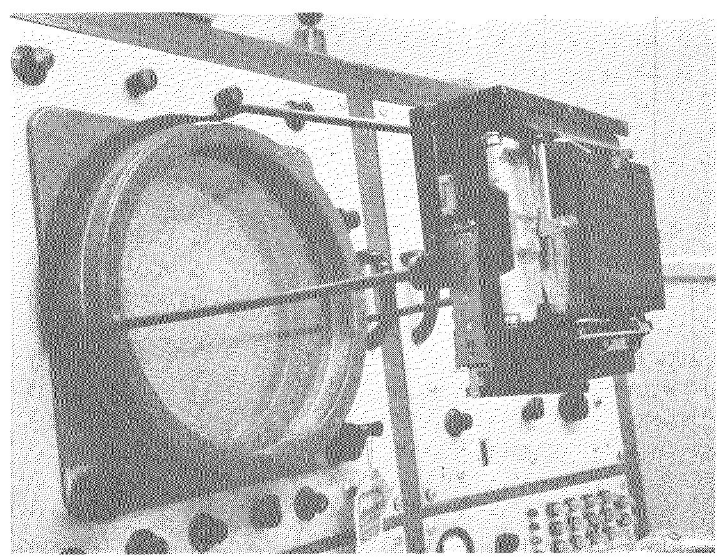

FIGURE 1.—WSR-57 radarscope with camera and mount.

dark during the time pictures are being taken as the camera support is an open framework (fig. 1) and the picture is exposed for one complete sweep of the scope.

The facsimile equipment, "Electronic Messenger", distributed by Western Union, is suitable for use on high quality telephone or microwave circuits, operates at 180 r.p.m., and transmits a picture 8.5×14 inches in 8.5 minutes during an ordinary long-distance telephone call. Transmission of the radarscope 4×5-inch Polaroid photograph takes about 4 minutes. The definition of the transmitted photograph is normally good, but is dependent upon the quality of the telephone circuits and the original photograph.

3. OPERATIONAL PROCEDURES

The radar composite network in Florida is activated on request from the District Meteorological Office in Miami or Project Mercury Weather Support Group. The radar stations at Daytona Beach and Tampa are notified to take a positive Polaroid photograph of their PPI scopes at a certain time, normally 10 minutes after the hour. The desired range and elevation angle are specified to insure uniformity. It is helpful in the compositing process to have a preselected range marker reinforced manually or with the strobe.

The radar meteorologists at Daytona Beach and Tampa mark out ground clutter, anomalous propagation, interference, and other non-meteorological indications and also place pertinent remarks on the edge of the photographs to be transmitted, using grease pencils. Cardinal points of the compass are also marked on the photographs for orientation as the azimuth angles are often difficult to read on the transmitted facsimile copies.

When the photographs are ready, the radar meteorologists at the stations place consecutive long-distance telephone calls to Miami. When verbal contact has been established, the facsimile equipment at the radar station and at Miami are switched into the line and the picture is transmitted. At the conclusion of the transmission, the line is switched back to voice to verify receipt and exchange any relevant information.

Upon receipt at Miami, the photographs are enlarged using an opaque projector and composited by tracing the three pictures on a 1:5,000,000 Mercator chart of Florida and adjacent areas. In areas of overlapping radar coverage a system of shading or stippling can be used to indicate the portion seen by each radar. After the composite is traced from the photographs, supplemental information such as intensity, location and movement of cells or areas, and the heights of cloud tops, is indicated on the chart by arrows and written remarks. Shading may be used to indicate the more intense echoes rather than areas of overlapping coverage. This is obtained from remarks or coordinates supplied by the radar meteorologists, as the transmitted photographs do not show intensity gradations.

An alternate method of preparing the composite that has been used at Miami is to trace the photographs without enlargement on a transparent acetate containing an outline map of Florida. However, this is not as satisfactory a method as using the opaque projector which enlarges the photographs and composite to any desired size.

The time required to prepare the radar composite usually includes 3 minutes for photography, 6 minutes per station for phone contact and facsimile transmission, and 3 minutes to complete the tracings after the last transmission. Thus, the completed radar composite is available to the Miami forecaster and ready for transmission to Cape Canaveral within 18 minutes after the radarscope photographs are taken.

Echo position errors introduced by this process of compositing have not been serious from the standpoint of operational forecasting. While greater accuracy can be achieved through various refinements which are being considered, the time required for more elaborate techniques must be weighed against the advantages of speed and simplicity.

Experience has revealed frequent discrepancies in the shape and extent of echoes when viewed by two or more radars. These discrepancies can be reduced through special efforts to insure uniformity of observational techniques, but differences will remain due to numerous technical factors. These include such items as attenuation, beam width distortion, and differences in sampling altitude due to variations in range. One of the marked advantages of the compositing procedure described here is that these differences can be detected and indicated in the areas of overlapping coverage.

4. EXAMPLES OF RADAR COMPOSITING

CASE OF MARCH 31, 1961

The surface chart at 1800 GMT, March 31, 1961 (fig. 2) shows a low pressure area centered over northern Alabama with a cold front extending south-southwestward across the Gulf of Mexico. A well-organized squall line, considerably in advance of the cold front, extends from eastern South Carolina across northern Florida into the Gulf.

The radar composite for 2005 GMT (fig. 3) distinctly shows the squall line as a continuous band of echoes oriented northeast-southwest across Florida from south of Jacksonville to north of Tampa. A narrow band of cells, extending north-south in advance of the main band, was located just east of Cape Canaveral (station 794). At Miami only a few scattered echoes were observed as the range to the main precipitation band was in excess of 200 n. mi.

The arrow in the Gulf of Mexico in figure 3 points to a strong echo that was observed by Daytona Beach at a distance of over 200 n. mi., thus revealing the existence of a strong convective cell embedded in the large precipitation area observed by Tampa radar. Significantly, a 75 n. mi. segment of the main band west of Florida was not seen by Daytona Beach radar, apparently because of attenuation or because the radar beam was overshooting

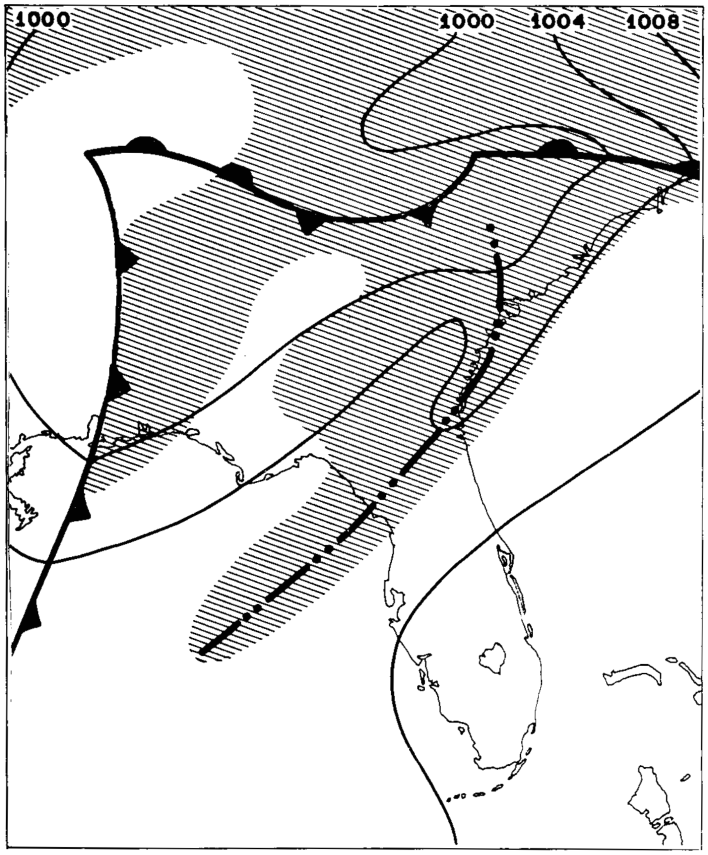

FIGURE 2.—Surface chart, 1800 GMT, March 31, 1961. Shaded areas are precipitation patterns as determined from synoptic analysis.

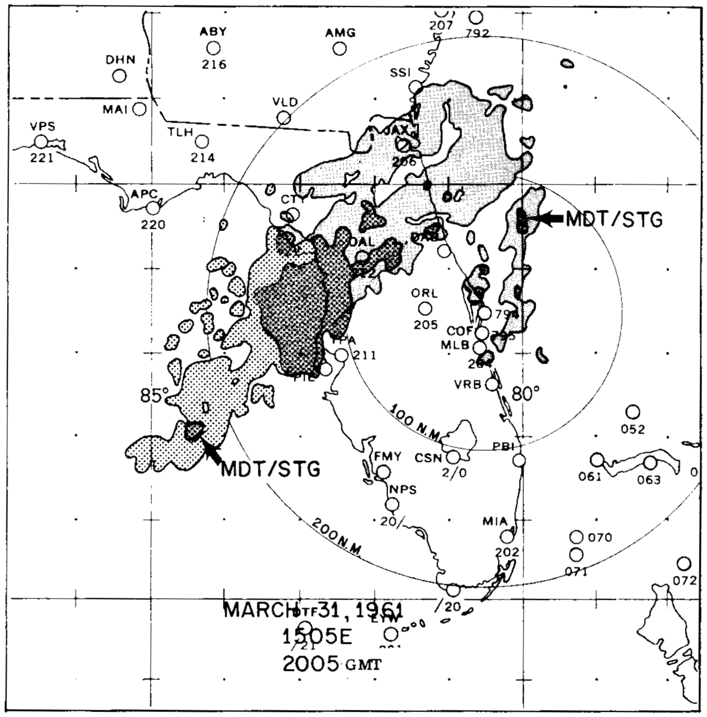

FIGURE 3.—Radar composite, 2005 GMT, March 31, 1961. Daytona Beach echo is shaded; Tampa, stippled; Miami, clear. Darkest stippling shows echos observed by more than one station. MDT=moderate; STG=strong.

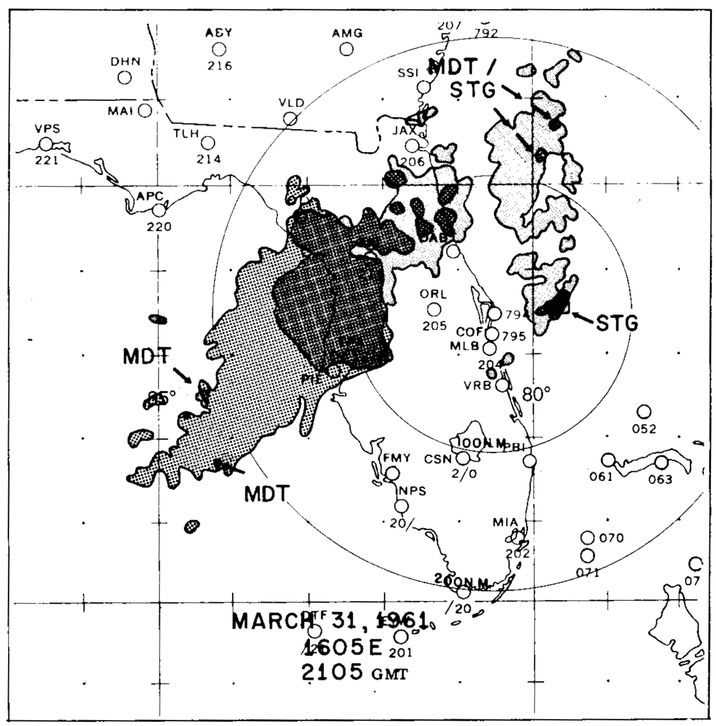

FIGURE 4.—Radar composite, 2105 GMT, March 31, 1961.

the top of the precipitation layer. Consequently, without the addition of the Tampa radarscope photograph the extent and continuity of the squall line would not have been evident from the Daytona Beach radar observation alone.

Boucher and Wexler [3] have pointed out that recognition of precipitation cells as a line is contingent upon the maximum range of detection of the radar for the different cells. Radar composites overcome this problem to a large extent by effectively increasing the degree of radar coverage. The use of composites helps to verify or refute the impressions gained from a single radar as to intensification or dissipation of a line by variations in length or thickness.

Figure 4 is the radar composite for 2105 GMT. Daytona Beach radar continued to show individual cells in the Gulf, but none of the intervening main percipitation band lying offshore that was evident on the Tampa radarscope. In the Atlantic, several strong cells east of Jacksonville, Fla., were observed by both Daytona Beach and Tampa; however, Tampa radar did not "see" the portion of the main band extending east of the Florida Peninsula. A strong cell located in the band of echoes east of Cape Canaveral was observed by all three radars, but only Daytona Beach saw the entire band. This is a good illustration that the radar composite reveals the squall line in greater detail than is otherwise possible, indicating precipitation in areas that may appear clear of echoes on an individual radarscope. It is also evident that the distant echoes observed simultaneously on two or more radarscopes may be moderate or strong cells since they are intense enough

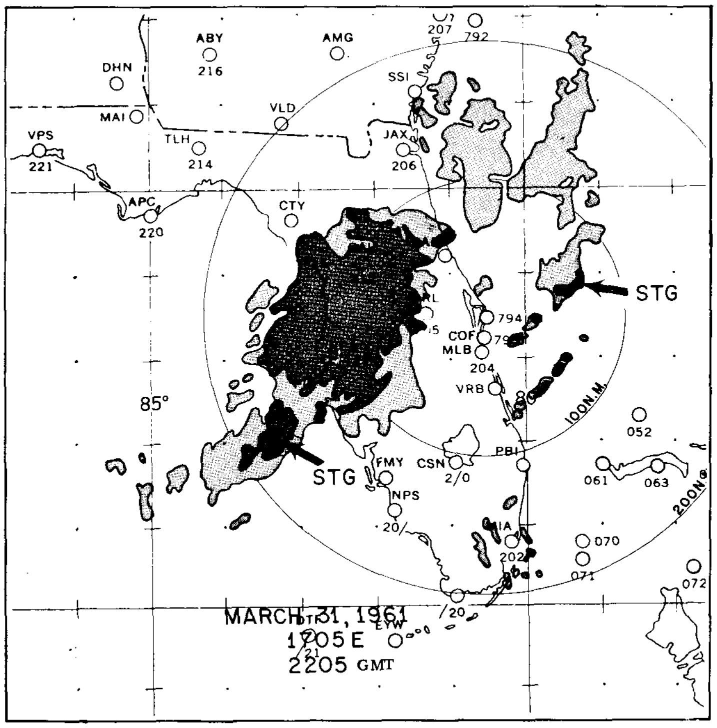

FIGURE 5.—Radar composite, 2205 GMT, March 31, 1961.

or have sufficient vertical extent to be observed at long range. Although such echoes are suspected of being moderate or strong cells, the intensities indicated on the composites are based on observations made by the radar meteorologists.

On the radar composite for 2205 GMT (fig. 5) the widest portion of the main band, advancing at approximately 20 kt., had progressed into central Florida. There was by then a definite break in the squall line where the main band crossed the Atlantic coastline. A narrow north-south band was still in evidence east of Cape Canaveral with many small individual cells at its southern extremity. The strong cell in the Atlantic northeast of Cape Canaveral and the large echo southwest of Tampa were visible on the radarscopes of all three stations.

Coded radar observations as transmitted by Daytona Beach, Miami, and Tampa at 2005, 2105, and 2205 GMT were plotted and compared with the radar composites prepared for the same times at Miami. In general, the coded observations exaggerated the area covered by echoes, showed fewer moderate to strong echoes than were indicated by the composites, and were frequently contradictory in describing the amount and intensity of echoes in overlapping areas. The difference between coded observations and composites points up the difficulty of adequately translating a visual radar observation into words.

CASE OF MAY 2, 1961

On May 2, 1961 a cold front advancing into the southeastern United States was preceded by a severe well-organized squall line (fig. 6). The radar composite for 0310 GMT, May 2 (fig. 7) shows the main precipitation band across Florida from Jacksonville to north of Tampa. The leading edge of this band contained a line of intense echoes about 20 n.mi. wide, which is evident to the west through north-northeast of Tampa. This line was observed on the radarscopes at both Daytona Beach and Tampa.

That this line was extremely active in the Gulf is verified by reports from a Weather Bureau DC–6 aircraft flying a reconnaissance mission over the Gulf prior to a scheduled Project Mercury manned space flight. At 0235 GMT, Mr. Robert H. Simpson, Deputy Director of Meteorological Research, who was aboard the aircraft, reported the squall line as very severe and continuous. Following this report, the aircraft flew northeast to Tampa paralleling the squall line which was described as solid to the northwest with continuous lightning.

The Radar Summary Chart for 0300 GMT (fig. 8) as prepared at Kansas City and transmitted over the National Facsimile Network also shows the squall line across northern Florida and over the Gulf west of Tampa. When this chart is compared to the radar composite for the same time (fig. 7), the most striking feature is the sharp areal detail obtained by compositing radar photographs as contrasted to the smooth general echo areas given by coded radar observations. Leading and trailing edges of precipitation areas can be closely located on radar composites. Furthermore, the squall line west of Tampa on the Radar Summary Chart is labeled "scattered, moderate", whereas the radar composite and the reconnaissance reports indicate a continuous line. One of the advantages of the composite system is that it practically eliminates the subjectivity involved in taking, coding, and decoding radar observations.

Figure 9, the radar composite for 0810 GMT, shows that the main band of echoes had moved south of Daytona Beach and that a new band of broken echoes had formed farther east. In the main precipitation band, the line of intense echoes (dark stippling) is now broken and appears weaker over the Gulf. The main band, moving at 20 to 25 kt., was catching up to an increasing area of precipitation (over the southern tip of Florida) which had been moving eastward at about 10 kt. The extent of weather activity on the Gulf side of Florida is readily apparent. By this hour, however, the importance of Tampa's radar contribution had diminished as most of the squall line was within range of the Miami radar. Nevertheless, the Tampa radar helped to define the trailing edge of the precipitation pattern because of its location north of the squall line.

Three hours later at 1110 GMT (fig. 10), the main precipitation band had reached southern Florida with the leading edge of the band near Miami. The band was moving out of range of the Daytona Beach radar so that this radar composite is probably not representative of the true extent of the precipitation band east of Cape Canaveral. The area of precipitation over the southern tip of

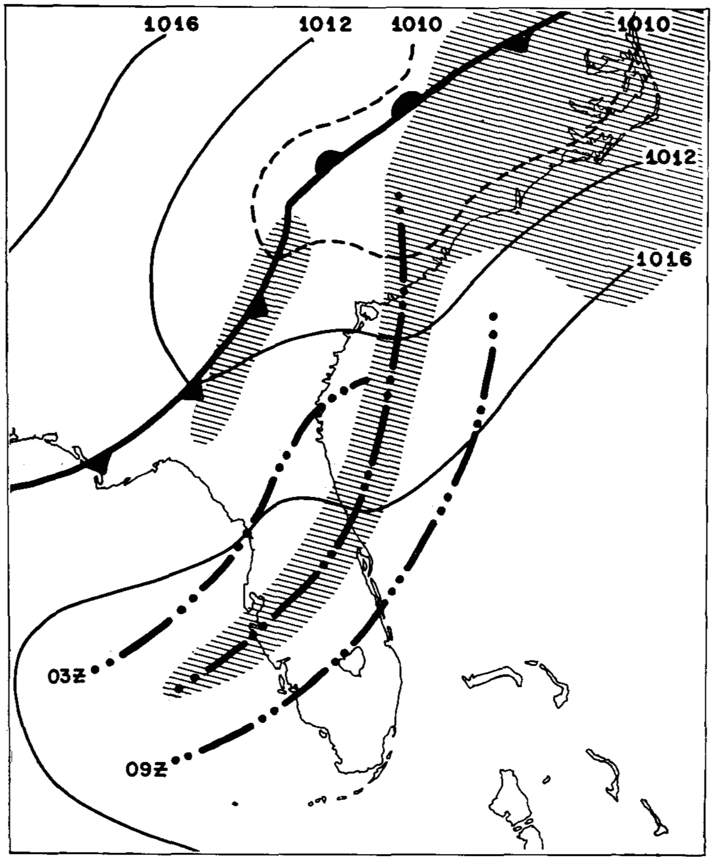

FIGURE 6.—Surface chart, 0600 GMT, May 2, 1961. Shaded areas are precipitation pattern as determined from synoptic analysis.

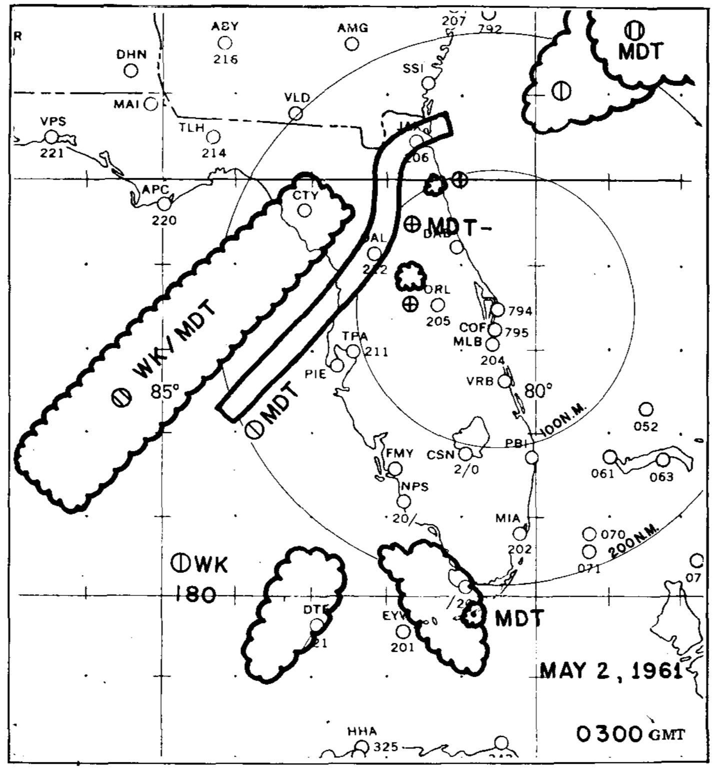

FIGURE 8.—Radar Summary Chart, 0300 GMT, May 2, 1961, prepared from coded observations and routinely transmitted over the facsimile network.

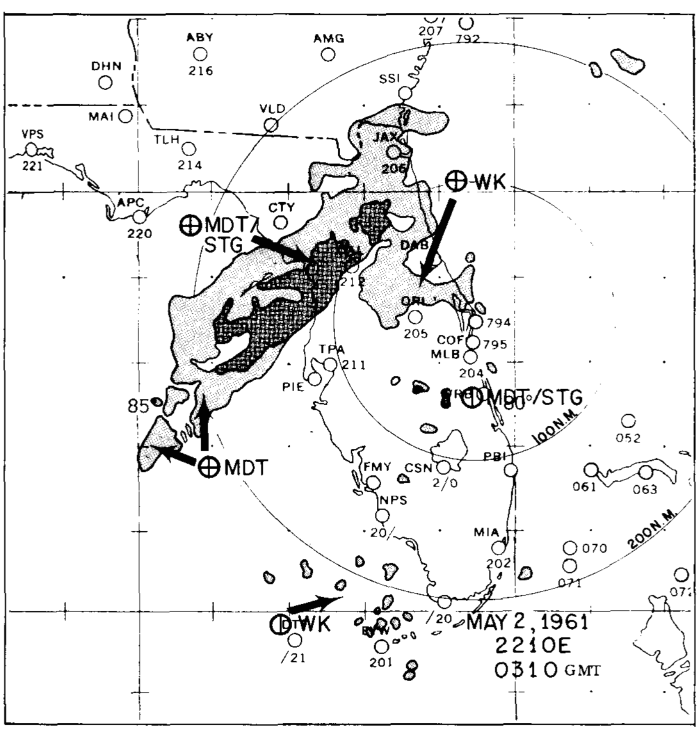

FIGURE 7.—Radar composite, 0310 GMT, May 2, 1961. WK=weak.

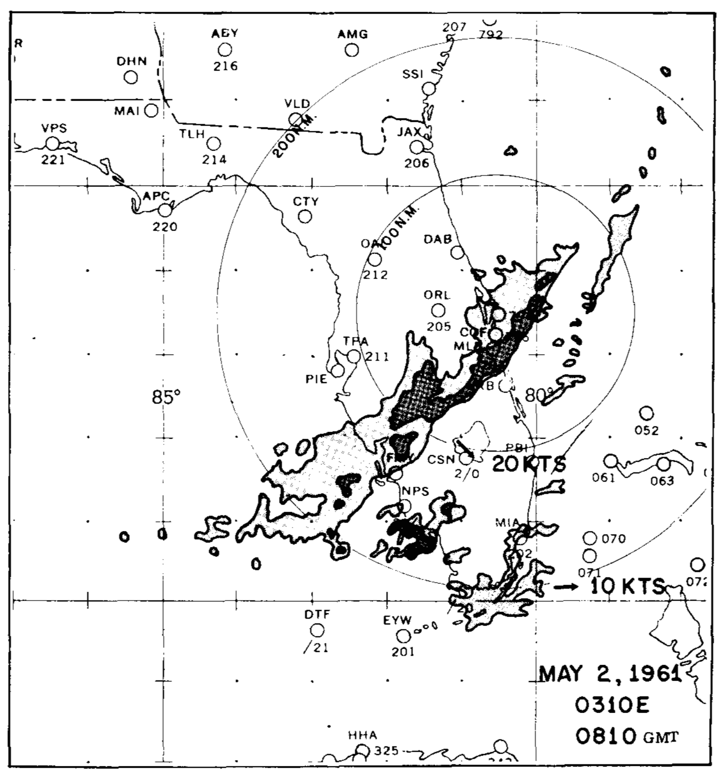

FIGURE 9.—Radar composite, 0810 GMT, May 2, 1961. Arrows show direction of movement of radar echo band.

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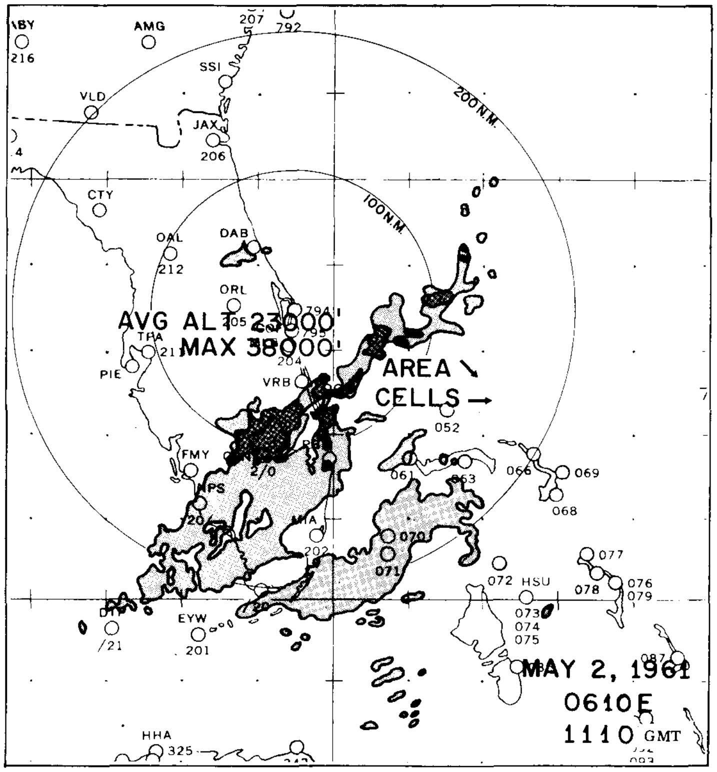

FIGURE 10.—Radar composite, 1110 GMT, May 2, 1961.

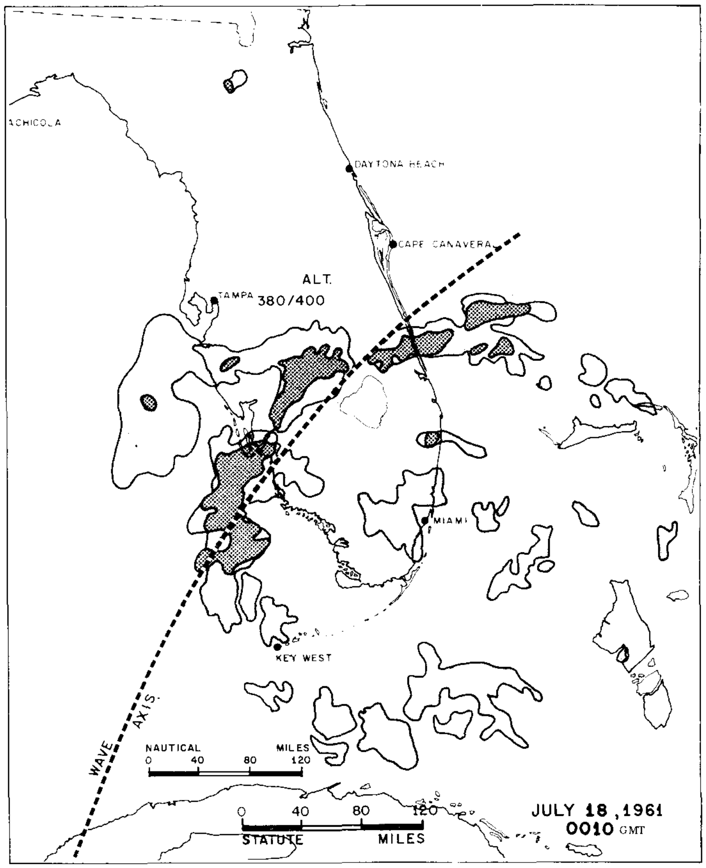

FIGURE 11.—Radar composite, 0010 GMT, July 18, 1961.

Florida had increased in size and moved eastward toward the Bahamas. One hour later the two bands joined into one immense precipitation area which continued eastward into the Bahamas and dissipated.

Radar composites for May 2, 1961 were prepared hourly from 0310 to 1310 GMT during the period when the squall line moved across the Florida Peninsula. These radar composites enabled forecasters at Miami and Cape Canaveral to follow the progress of the squall line in greater detail, to issue timely warnings, and to prepare more accurate forecasts than would otherwise have been possible. In this instance, radar composites enabled Project Mercury Weather Support Group meteorologists to time the squall line passage at Cape Canaveral more exactly than would have been possible using coded radar observations or individual radarscope presentations.

CASE OF JULY 18–19, 1961

The radar composite for 0010 GMT, July 18, 1961 (fig. 11) shows the precipitation echo distribution associated with a moderate easterly wave moving westward into the Gulf of Mexico at about 10 kt. In figure 11 there is a broken, cyclonically-curved band of echoes near the wave axis, but the majority of echoes are oriented in east-west lines or spiral band segments parallel to the wind flow as is commonly observed with easterly waves. Precipitation was occurring, at the time of this composite, east of the wave over western Cuba, the western Caribbean, Nicaragua, and Honduras, where the wave intersected the Intertropical Convergence Zone. However, only echoes north of the Straits of Florida appear on the composite since the southern portion of the wave was beyond radar range.

As the wave entered the Gulf of Mexico it moved under the eastern edge of a low pressure area in the upper troposphere resulting in divergence through a deep layer to the west of the wave axis and a corresponding increase in amplitude [4]. Figure 12, the radar composite for 2310 GMT, July 18, gives a clear indication of the growth of precipitation echoes that accompanied this intensification. Precipitation decreased over Florida during the evening of July 18 as the wave moved westward, and by 0510 GMT, July 19 the only significant echoes were over the Gulf just west of Florida.

By midday on the 19th, however, a small 1015-mb. surface Low developed in the easterly wave over the northeastern Gulf of Mexico causing a rapid increase in clouds and precipitation over central Florida. Figure 13 shows the echo configurations over Florida when the Low was west of Tampa. From this position the Low drifted slowly north-northeastward without intensifying and dissipated over land on the following day.

Radar composites prepared during the passage of the easterly wave and subsequent low pressure development over the Gulf were especially helpful to Project Mercury Weather Support Group meteorologists preparing fore-

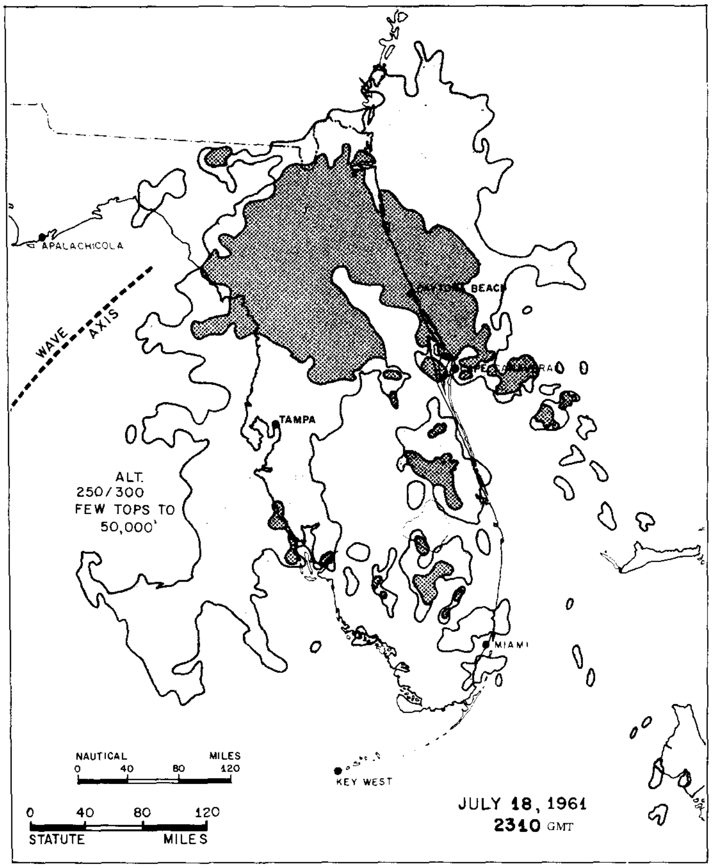

FIGURE 12.—Radar composite, 2310 GMT, July 18, 1961.

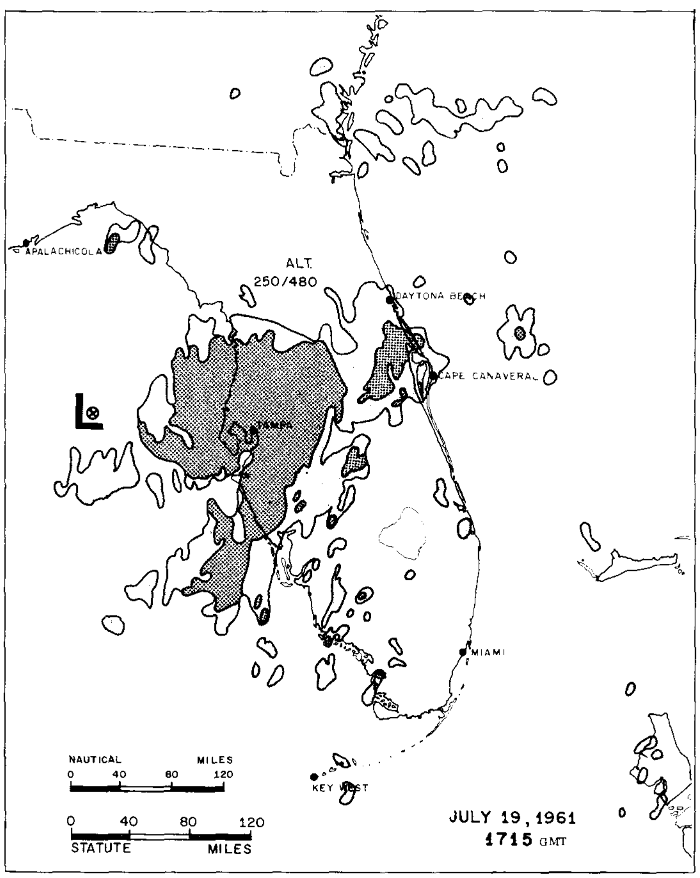

FIGURE 13.—Radar composite, 1715 GMT, July 19, 1961.

casts for the second sub-orbital Mercury manned flight. Availability of these composites increased the confidence of the forecasters in their predictions and enabled them to make correct recommendations at the times when critical decisions had to be made.

5. CONCLUSION

Manual radar composites prepared on a regional basis have proved feasible and valuable in operational use. They are particularly useful (1) in extending the area of radar coverage available to a forecast office providing a more accurate portrayal of conditions than is possible from coded observations, and (2) in providing multiple surveillance of important areas thus revealing many features not apparent to a single radar.

The present network adequately covers the area of interest for operational forecasting at Cape Canaveral. However, for other forecasting purposes the addition of more radar stations to the network would increase the total area covered and provide further overlap in the event of station outages. Six to eight radar stations appear to be the maximum that could be effectively incorporated into a single network, assuming one facsimile receiver similar to the type used at Miami at the compositing station and preparation of hourly radar composites. Additional stations could be included in a single network if two receivers were used or if composites were prepared less frequently.

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